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Ishihama et al.

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(54) **VANE PUMP INCLUDING OUTER SIDE PLATE DEFINING HIGH AND LOW PRESSURE NOTCH GROOVES OF DIFFERING LENGTHS ADJACENT THE HIGH AND LOW DISCHARGE PORTS FOR IMPROVED NOISE PERFORMANCE**

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F04C 15/00	(2006.01)
F04C 15/06	(2006.01)
F01C 21/10	(2006.01)

(52) **U.S. Cl.**

CPC ***F04C 2/344*** (2013.01); ***F01C 21/108*** (2013.01); ***F04C 2/3446*** (2013.01); ***F04C 15/0049*** (2013.01); ***F04C 15/06*** (2013.01)

(58) **Field of Classification Search**

USPC 418/268, 26, 28, 15, 157, 189

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,518,380	A *	5/1996	Fujii et al.	418/26
6,068,461	A *	5/2000	Haga et al.	418/180
6,120,256	A *	9/2000	Miyazawa	417/220
6,203,303	B1 *	3/2001	Fujiwara et al.	418/269
2009/0047141	A1 *	2/2009	Yamamuro et al.	417/218

FOREIGN PATENT DOCUMENTS

JP	3573242	B2 *	10/2004
KR	2005011168	A *	1/2005
WO	WO2005/005837		1/2005

OTHER PUBLICATIONS

English Machine Translation of WO 2005005837 A1.*
English Machine Translation of JP 3573242 B2.*
English Abstract of KR 2005011168 A.*
English Abstract of KR 2005011168 A (Derwent Abstract and lone figure, printed Nov. 7, 2013).*

* cited by examiner

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(57) **ABSTRACT**

In a vane pump, when discharge pressures of respective discharge ports are different from each other, an extension length L1 of a notch groove which is provided in the discharge port in a side of a high discharge pressure is set longer than an extension length L2 of a notch groove which is provided in the discharge port in a side of a low discharge pressure.

6 Claims, 8 Drawing Sheets

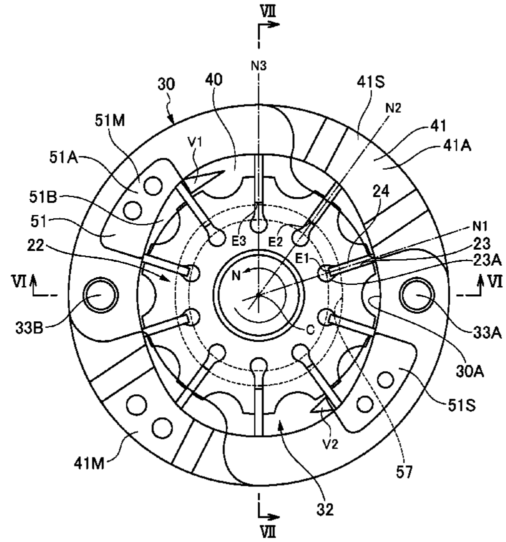
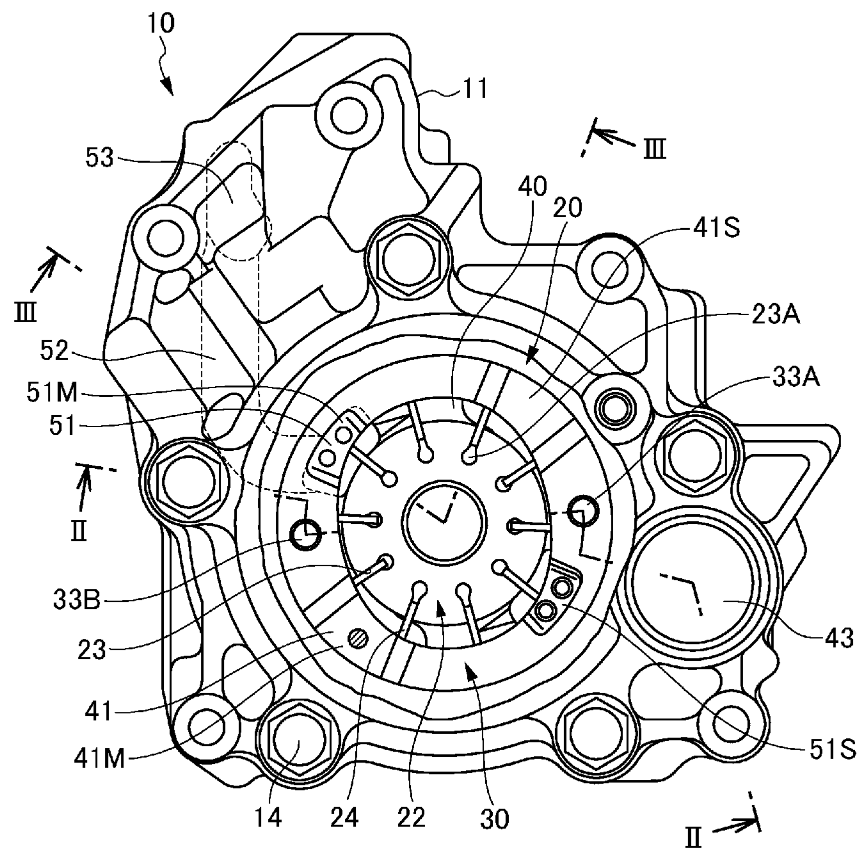


FIG.1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11
53
III
40
20
41S
III
23A
52
33A
51M
51
II
33B
23
43
41
41M
51S
14
24
22
30
II

FIG.2

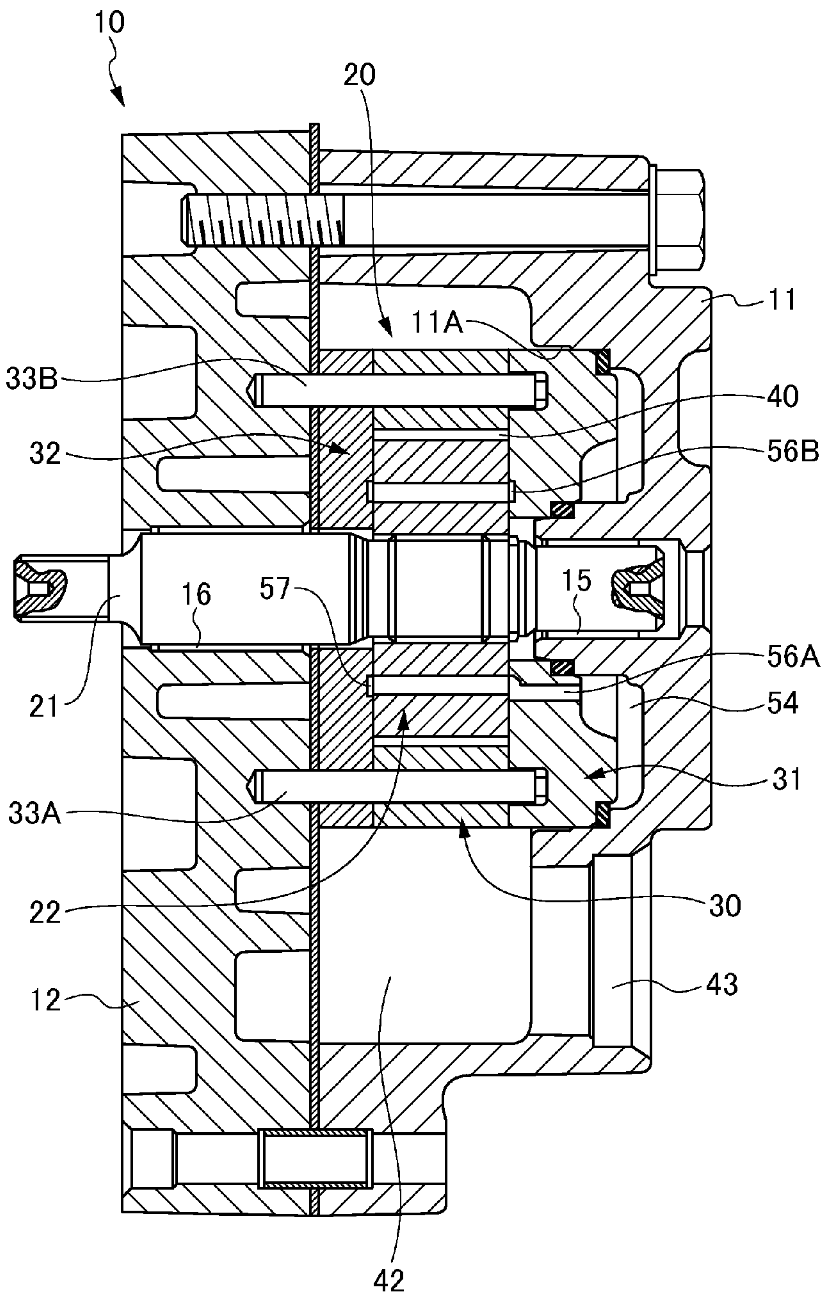


FIG.3

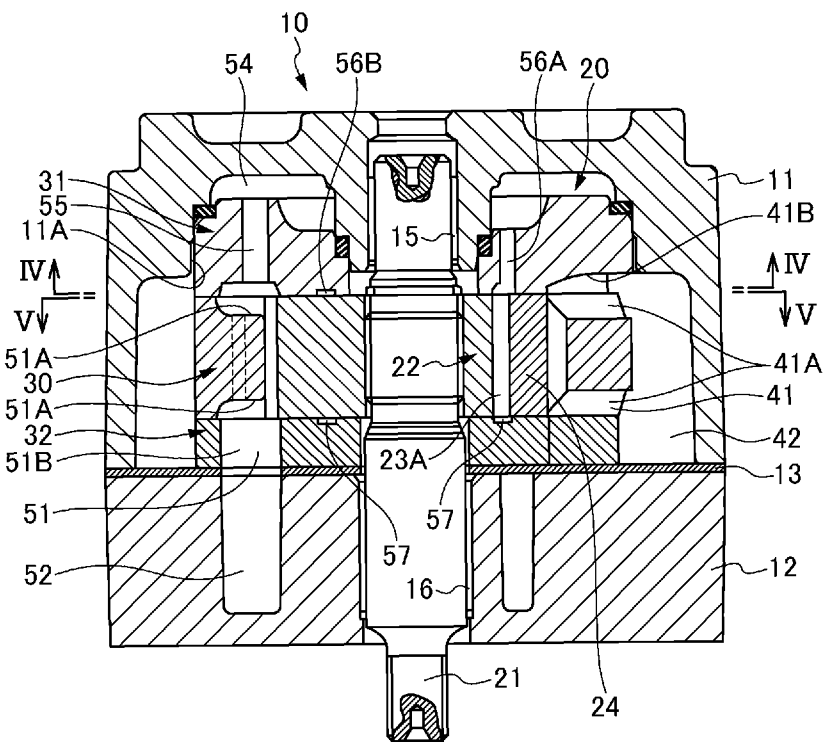

10
54
56B
56A
20
31
55
11A
11
41B
15
IV
V
IV
V
51A
30
22
41A
41
51A
32
23A
42
51B
13
51
57
57
52
16
12
21
24

FIG.4

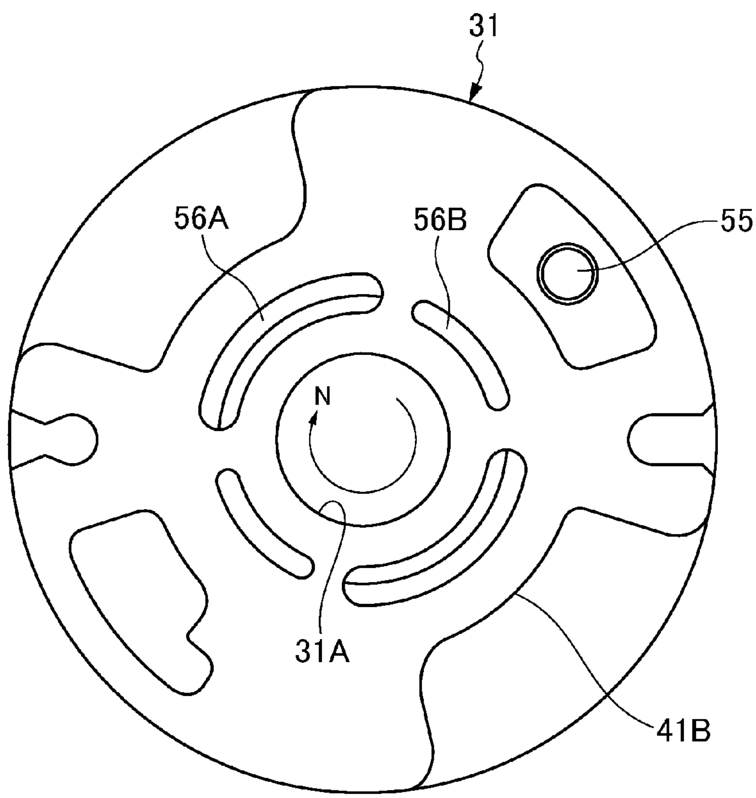
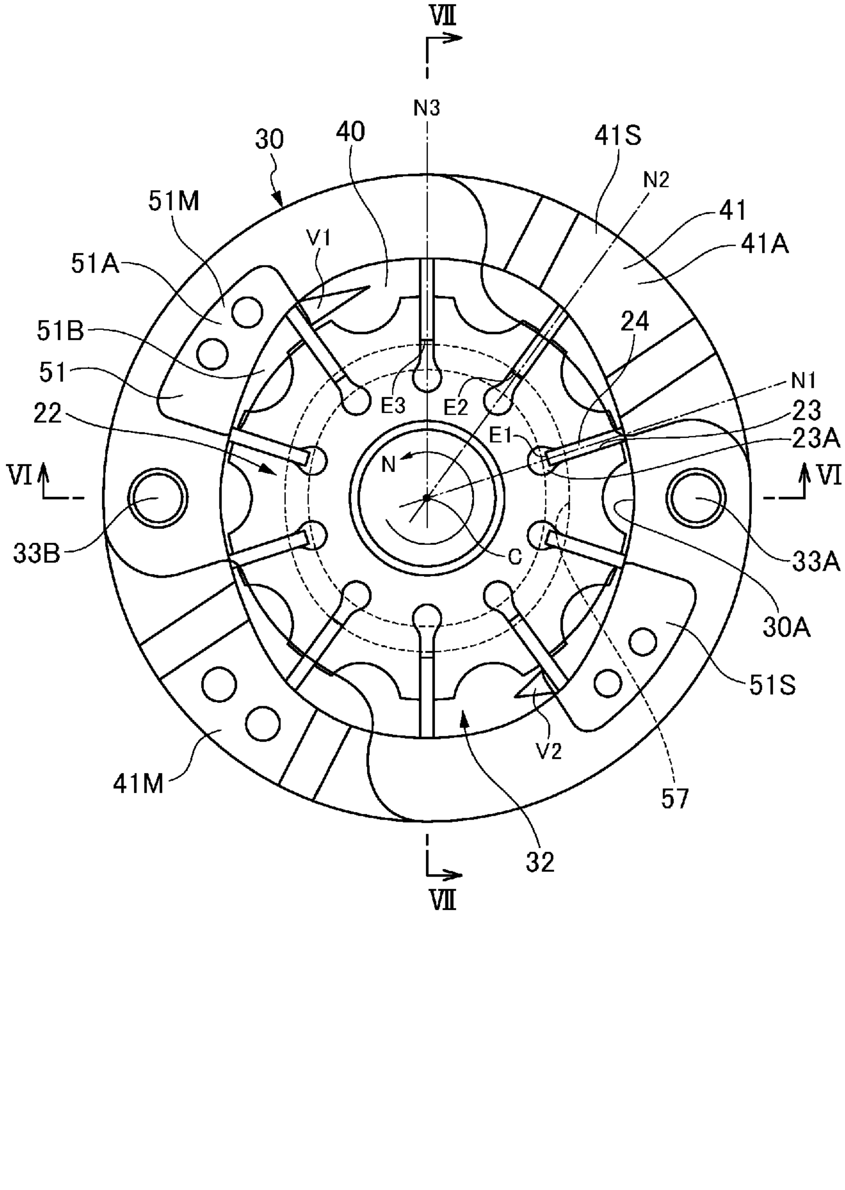


FIG.5



VII
N3
30
40
41S
N2
51M
V1
41
41A
51A
24
51B
N1
51
E3
E2
23
22
E1
23A
VI
N
VI
33B
C
33A
30A
51S
V2
41M
57
32
VII

FIG.6A

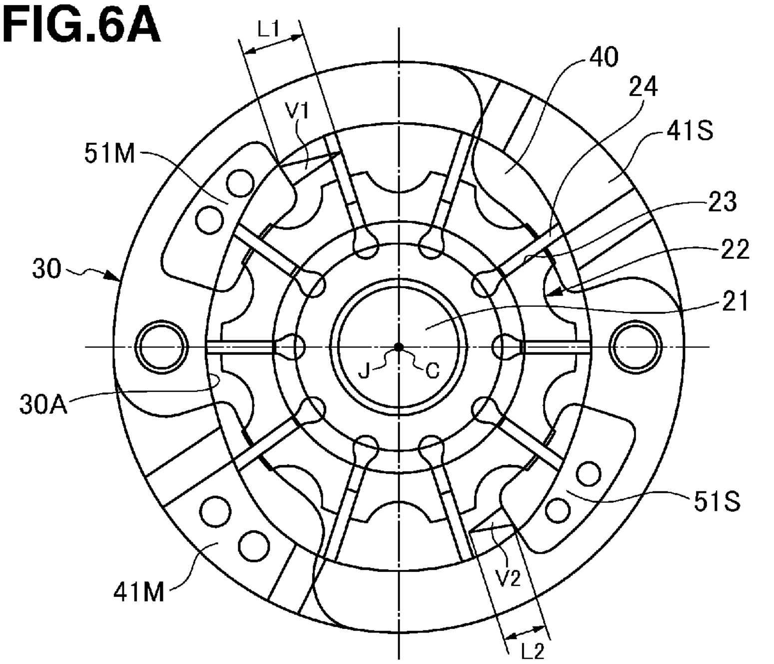

L1
40
24
41S
V1
51M
23
22
30
21
J
C
30A
51S
V2
41M
L2

FIG.6B

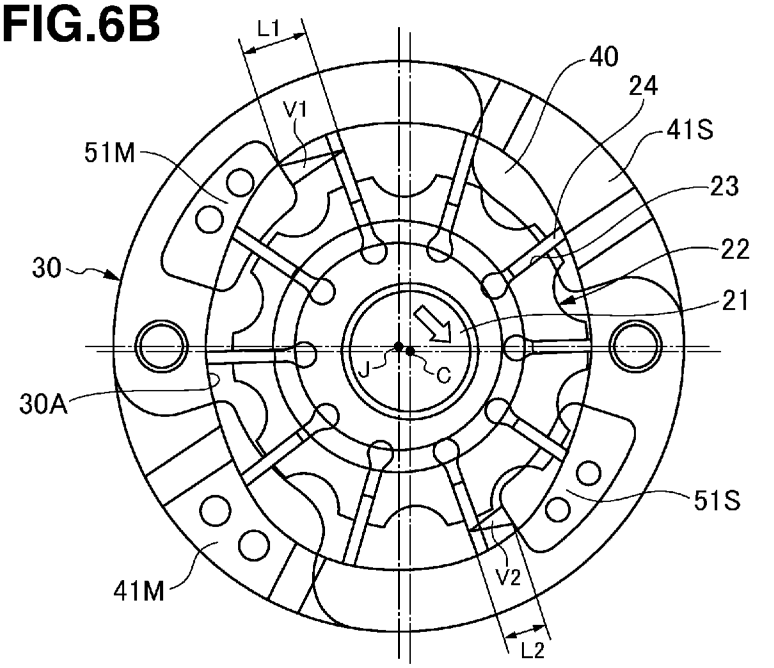
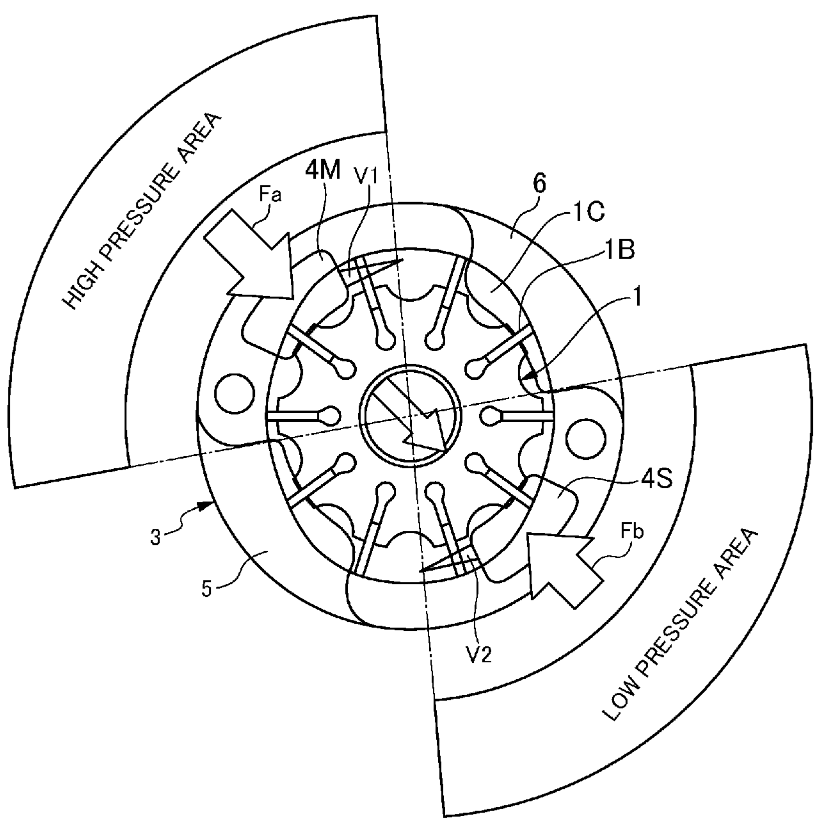
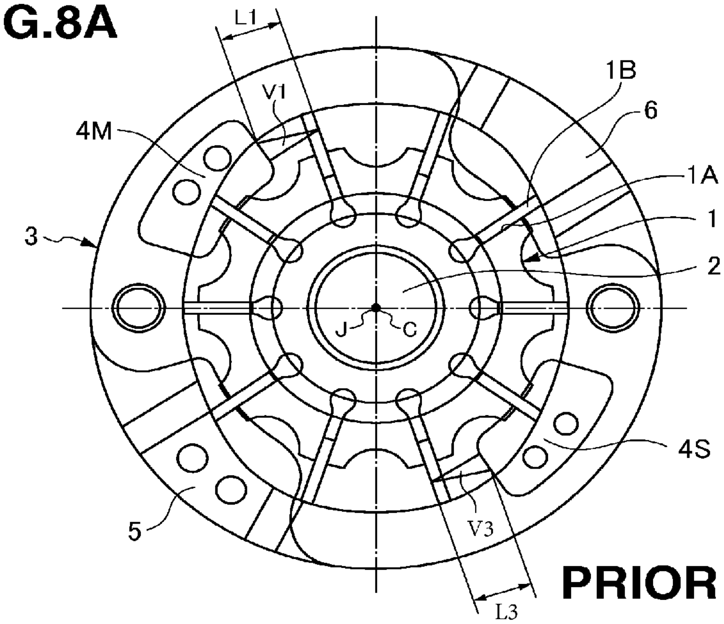

L1
40
24
41S
V1
51M
23
22
30
21
J
C
30A
51S
V2
41M
L2

FIG.7



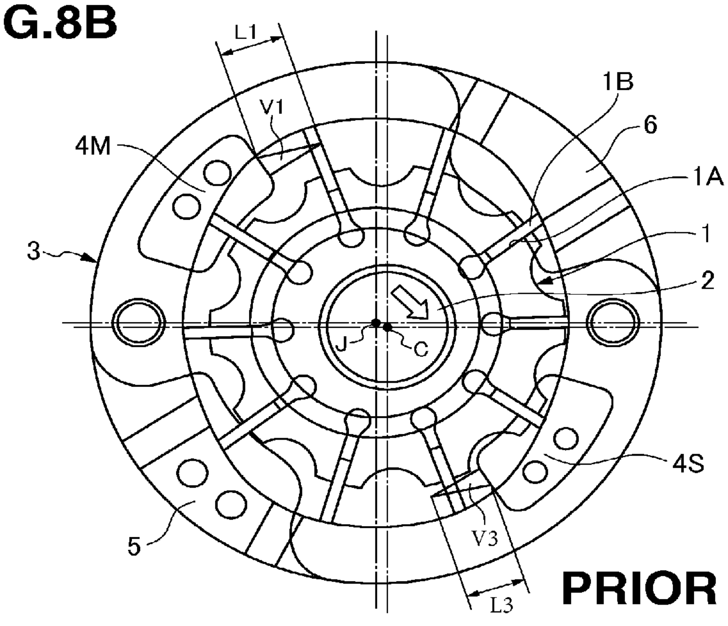
PRIOR ART

FIG.8A



PRIOR ART

FIG.8B



PRIOR ART

VANE PUMP INCLUDING OUTER SIDE PLATE DEFINING HIGH AND LOW PRESSURE NOTCH GROOVES OF DIFFERING LENGTHS ADJACENT THE HIGH AND LOW DISCHARGE PORTS FOR IMPROVED NOISE PERFORMANCE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a vane pump.

2. Description of the Related Art

As a vane pump, as described in WO2005/005837 (patent document 1), there is a structure having a rotor which is connected to a rotating shaft pivoted to an inner portion of a housing so as to rotate. A cam ring is arranged in such a manner as to surround the rotor in the inner portion of the housing. A plurality of vanes are slidably arranged in a plurality of vane grooves provided in a radial direction of the rotor. A plurality of pump chambers are defined by the adjacent vanes in the periphery of the rotor. A plurality of discharge ports corresponding to the pump chambers carrying out a compression stroke are provided to be opposed in a diametrical direction of the rotor. Notch grooves are extended in an inverse direction to a rotor rotation forward direction from hole edges in the inverse direction of the respective discharge ports. In this vane pump, a communication start point between each of the pump chambers and each of the discharge ports is quickened by the notch groove, and a communication time between the pump chamber and the discharge port becomes longer with respect to a rotating speed of the vane. Accordingly, since a moving time to the pump chamber of a working fluid pressure within the discharge port becomes longer, a hydraulic pressure change of the working fluid within the pump chamber becomes smaller. As a result, it is possible to reduce a serge pressure within the pump chamber and it is possible to lower an abnormal noise generation.

Further, as the vane pump, as described in Japanese Patent No. 3573242 (patent document 2), there is a structure in which a plurality of discharge ports are divided into a main discharge port which always carries out a discharge, and the other sub discharge port. For example, in the vane pump which is used in a power steering apparatus of a vehicle, it is desired to supply a sufficient flow rate to a fluid equipment of a steering in a low rotation area, and hold down an unnecessarily great flow rate for lowering uselessly consumed horse power in a high rotation area. Accordingly, in the low rotation area, a sufficient flow rate of pressure fluid is supplied to the fluid equipment from both of the main discharge port and the sub discharge port. Further, in the high rotation area, the pressure fluid is supplied to the fluid equipment only from the main discharge port, and the discharge oil of the sub discharge port is flowed back as surplus oil to a tank side (or an suction port corresponding to the same sub discharge port), thereby achieving a reduction of the consumed horse power.

FIGS. **7**, **8**A and **8**B show the conventional vane pump mentioned above. Reference numeral **1** denotes a rotor. Reference symbol **1**A denotes a vane groove. Reference symbol **1**B denotes a vane. Reference symbol **1**C denotes a pump chamber defined by the adjacent vanes **1**B and **1**B. Reference numeral **2** denotes a rotating shaft. Reference numeral **3** denotes a cam ring. Reference symbol **4**M denotes a main discharge port. Reference symbol V**1** denotes a notch groove. Reference symbol **4**S denotes a sub discharge port. Reference symbol V**2** denotes a notch groove, and reference numerals **5** and **6** denote a suction port. An extension length L1 of the

notch groove V**1** of the main discharge port **4**M and an extension length L2 of the notch groove V**2** of the sub discharge port **4**S are set to the same length.

In the conventional vane pump mentioned above, in the case that the pressure fluid is supplied to the fluid equipment only from the main discharge port **4**M, the working fluid pressure of the main discharge port **4**M connected to a supply flow path to the fluid equipment becomes higher, and the working fluid pressure within the sub discharge port **4**S connected to the tank side (or the suction port) becomes lower. As a result, as shown in FIG. **7**, a relationship Fa>Fb is established between a pressure Fa which the working fluid pressure within the main discharge port **4**M applies to the rotor **1** via the pump chamber **1**C, and a pressure Fb which the working fluid pressure within the sub discharge port **4**S applies to the rotor **1** via the pump chamber **1**C, on a diameter of the rotor **1** which connects the main discharge port **4**M and the sub discharge port **4**S through the center of the rotor **1**. The pressure difference Fa/Fb makes a center C of the rotor **1** displace from a center J of the cam ring **3** close to the sub discharge port **4**S at a degree of a play of a serration by which the rotor **1** is connected to the rotating shaft **2** as shown in FIG. **8**A to FIG. **8**B. In accordance with this, the center C of the rotor **1** is offset from the center J of the cam ring **3**, and in comparison with a timing at which the one vane **1**B runs into the notch groove V**1** of the main discharge port **4**M, a timing at which the another vane **1**B runs into the notch groove V**2** of the sub discharge port **4**S becomes faster, in two vanes **1**B and **1**B which are opposed to each other while holding the center C of the rotor **1** therebetween. Accordingly, the timings at which the respective pump chambers **1**C defined by the vanes **1**B are communicated respectively with the main discharge port **4**M and the sub discharge port **4**S are deviated from each other, and phases of pulsations of the hydraulic pressure within the respective discharge ports **4**M and **4**S are further deviated from each other, thereby causing an abnormal noise generation.

SUMMARY OF THE INVENTION

An object of the present invention is to synchronize phases of pulsations of a hydraulic pressure within respective discharge ports with each other so as to hold down an abnormal noise generation, at a time when discharge pressures of the respective discharge ports are different from each other, in a vane pump having a plurality of discharge ports which are provided with notch grooves for reducing a surge pressure within a pump chamber defined by adjacent vanes.

In one embodiment of the present invention, there is provided a vane pump comprising: a rotor which is connected to a rotating shaft pivoted to an inner portion of a housing so as to rotate; a cam ring which is arranged in such a manner as to surround the rotor in the inner portion of the housing. A plurality of vanes are slidably arranged in a plurality of vane grooves provided in a radial direction of the rotor; a plurality of pump chambers are defined by the adjacent vanes around the rotor. A plurality of discharge ports corresponding to the pump chambers carry out a compression stroke, which are provided to be opposed in a diametrical direction of the rotor. Notch grooves are provided each of which is extended from a hole edge in an inverse direction to a rotor rotating forward direction of each of the discharge ports to the inverse direction. When discharge pressure of the discharge ports are different from each other, an extension length of the notch groove which is provided in the discharge port in a side of a high discharge pressure is set longer than an extension length of the notch groove which is provided in the discharge port in a side of a low discharge pressure.

In another embodiment of the present invention, there is provided the vane pump, wherein two vanes which are positioned in both sides while holding a center of the rotor therebetween so as to be opposed are provided on a diameter of the rotor. When the center of the rotor displaces close to the discharge port in the side of the low discharge pressure at a degree of a play with the rotating shaft, a timing at which one vane runs into a leading end of the notch groove of the discharge port in the side of the high discharge pressure is set to the same as a timing at which another vane runs into a leading end of the notch groove of the discharge port in the side of the low discharge pressure.

In another embodiment of the present invention, there is provided the vane pump, wherein in the case that the plurality of discharge ports consist of a main discharge port which always carries out a supply of the discharge fluid, and the other sub discharge port, the main discharge port is the discharge port in the side of the high discharge pressure, and the sub discharge port is the discharge port in the side of the low discharge pressure.

In another embodiment of the present invention, there is provided the vane pump, wherein the notch groove is a V-shaped notch groove extended in such a manner as to be narrowed little by little from a hole edge in an inverse direction to a rotating forward direction of the rotor in the inverse direction, in the main discharge port and the sub discharge port.

In another embodiment of the present invention, there is provided the vane pump, wherein the extension length of the notch groove of the main discharge port and the extension length of the notch groove of the sub discharge port are set according to an amount of a play of a serration connection between the rotating shaft and the rotor, and a pressure difference of a discharge pressure between the main discharge port and the sub discharge port.

In another embodiment of the present invention, the vane pump is a fixed displacement type vane pump.

In accordance with the present embodiment, the following operations and effects can be achieved.

(a) When the discharge pressures of the respective discharge ports of the vane pump are different from each other, the extension length of the notch groove which is provided in the discharge port in the side of the high discharge pressure is set longer than the extension length of the notch groove which is provided in the discharge port in the side of the low discharge pressure. As a result, a relationship Fa>Fb is established between a pressure Fa which the working fluid pressure within the discharge port in the side of the high discharge pressure applies to the rotor via the pump chamber, and a pressure Fb which the working fluid pressure within the discharge port in the side of the low discharge pressure applies to the rotor via the pump chamber, on the diameter of the rotor which connects the discharge port in the side of the high discharge pressure and the discharge port in the side of the low discharge pressure through the center K of the rotor. The pressure difference Fa/Fb makes the center K of the rotor displace from the center L of the cam ring at a degree of the play of the serration by which the rotor is connected to the rotating shaft, as shown in FIG. **6**A to FIG. **6**B, and goes on maintaining the rotor at the offset position in FIG. **6**B. Further, since the extension length A of the notch groove of the discharge port in the side of the high discharge pressure is longer than the extension length B of the notch groove of the discharge port in the side of the low discharge pressure (A>B), even if the center K of the rotor is offset from the center L of the cam ring as mentioned above, the timing at which the one vane runs into the leading end of the notch groove of the discharge port in the side of the high discharge pressure comes to the same as the timing at which the another vane runs into the leading end of the notch groove of the discharge port in the side of the low discharge pressure, in these two vanes which are opposed to each other while holding the center K of the rotor therebetween. Therefore, the timings at which the respective pump chambers zoned by the vanes are communicated respectively with the discharge port in the side of the high discharge pressure and the discharge port in the side of the low discharge pressure are the same, phases of the pulsations of the hydraulic pressure within the respective discharge ports are synchronized with each other, and it is possible to hold down an abnormal noise generation.

(b) In the vane pump in the item (a) mentioned above, when two vanes which are positioned in both sides while holding the center of the rotor therebetween and are opposed to each other are provided on the diameter of the rotor, and the center of the rotor displaces close to the discharge port in a side of the low discharge pressure at a degree of the play with the rotating shaft, the timing at which the one vane runs into the leading end of the notch groove of the discharge port in the side of the high discharge pressure is set at same time as the timing at which the another vane runs into the leading end of the notch groove of the discharge port in the side of the low discharge pressure.

(c) In the vane pump in the items (a) and (b) mentioned above, when the plurality of discharge ports consist of a main discharge port which always carries out a supply of the discharge oil, and the other sub discharge port, the main discharge port is constructed by the discharge port in the side of the high discharge pressure, and the sub discharge port is constructed by the discharge port in the side of the low discharge pressure, thereby achieving the items (a) and (b) mentioned above.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be more fully understood from the detailed description given below and from the accompanying drawings which should not be taken to be a limitation on the invention, but are for explanation and understanding only.

The drawings:

FIG. **1** is a side cross sectional view showing a vane pump;

FIG. **2** is a cross sectional view along a line II-II in FIG. **1**;

FIG. **3** is a cross sectional view along a line III-III in FIG. **1**;

FIG. **4** is a view as seen from an arrow along a line IV-IV in FIG. **3**;

FIG. **5** is a view as seen from an arrow along a line V-V in FIG. **3**;

FIG. **6**A and FIG. **6**B are schematic views showing a state before and after a rotor displaces on the basis of a hydraulic pressure of a discharge port in a side of a high discharge pressure, in the embodiment in accordance with the present invention;

FIG. **7** is a prior art schematic view showing a principle by which the rotor displaces on the basis of the hydraulic pressure of the discharge port in the side of the high discharge pressure; and

FIG. **8**A and FIG. **8**B are prior art schematic views showing a state before and after a rotor displaces on the basis of a hydraulic pressure of a discharge port in a side of a high discharge pressure, in a conventional example.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

A vane pump **10** shown in FIG. **1** to FIG. **5** is a fixed displacement type vane pump. The vane pump **10** is driven, for example, by a power of an internal combustion engine, and is employed as an oil pump for supplying a working fluid serving as a fluid to a fluid pressure utilizing equipment, for example, a hydraulic power steering and a hydraulic continuously variable transmission.

The vane pump **10** has a housing **11** which is provided with a concave portion (an accommodating chamber) **11**A accommodating a pump unit **20**, a cover plate **12** which covers an opening portion of the concave portion **11**A of the housing **11**, and a seal plate **13** which is pinched between the housing **11** and the cover plate **12**. The housing **11**, the cover plate **12** and the seal plate **13** are fastened by a plurality of bolts **14** so as to be fixed. The seal plate **13** covers a plurality of passage grooves or lightening grooves which are formed in the housing **11** and the cover plate **12** so as to seal.

The vane pump **10** is structured such that a rotating shaft **21** of the pump unit **20** is pivoted to bearings **15** and **16** which are provided in the housing **11** and the cover plate **12**, and a rotor **22** fixedly connected to the rotating shaft **21** via a serration is arranged in the concave portion **11**A of the housing **11**. The rotating shaft **21** and the rotor **22** are rotated by a power of the internal combustion engine.

The rotor **22** is structured, as shown in FIG. **5**, such that a plurality of vanes **24** are accommodated in a plurality of vane grooves **23** which are provided in a radial direction (a diametrical direction) so as to freely rise and set, respectively at a plurality of positions along a peripheral direction, and each of the vanes **24** is arranged so as to be slidable in a radial direction along the vane groove **23**. The rotor **22** is structured such that the vane groove **23** is open to an outer peripheral surface and both side surfaces.

The pump unit **20** is fitted and attached to the concave portion **11**A of the housing **11**, in such a manner that an inner side plate **31**, a cam ring **30**, and an outer side plate **32** are laminated in this order from a far side of the concave portion **11**A. These inner side plate **31**, the cam ring **30** and the outer side plate **32** are fixedly retained by the cover plate **12** from a lateral side in a state of being skewered by positioning pins **33**A and **33**B so as to be positioned in the peripheral direction, together with the seal plate **13** which is additionally provided in the outer side plate **32**. In this case, the side plates **31** and **32** are formed as a perforated disc shape, and have center holes **31**A and **32**A into which the rotating shaft **21** of the rotor **22** is inserted.

The cam ring **30** is formed as a tubular shape which has a circular outer peripheral surface, and an inner peripheral surface forming a cam surface **30**A by a cam curve which is similar to an oval, is fitted and attached to the concave portion **11**A of the housing **11**, and surrounds the rotor **22**.

The inner side plate **31** and the outer side plate **32** construct a pair of plates which pinch the rotor **22**, the vane **24** and the cam ring **30** from both sides. Accordingly, the cam ring **30** surrounds the rotor **22** and the vane **24** between both the side plates **31** and **32**, and forms a pump chamber **40** between an outer peripheral surface of the rotor **22** and the adjacent vanes **24**.

In the pump unit **20**, in a suction area corresponding to the pump chamber **40** which carries out a suction stroke, in an upstream side of a rotation forward direction of the rotor **22**, a suction port **41** (a suction port **41**A and a suction port **41**B) which are provided in the cam ring **30** and the inner side plate **31** are open, and a suction port **43** of the pump **10** is communicated with the suction port **41** via a suction passage **42** which is provided in the housing **11**. The oil is sucked into a suction area in which the pump chamber **40** is expanded in conjunction with a rotation of the rotor **22**.

In the present embodiment, the suction port **41** is provided at each of two positions which are opposed in a diametrical direction passing through the center C of the rotor **22** (a center J of the cam ring **30** and the inner side plate **31**). One of these two suction ports **41** is set to a suction port **41**M and another is set to a suction port **41**S. These two suction ports **41**M and **41**S are arranged so as to be point symmetrical with respect to the centers K and L.

On the other hand, in a discharge area corresponding to the pump chamber **40** which carries out a compression stroke, in a downstream side of the rotation forward direction of the rotor **22**, a discharge port **51** which is provided in the cam ring **30** and the outer side plate **32** is open, and a discharge port **53** of the pump **10** is communicated with the discharge port **51** (a discharge port **51**A and a discharge port **51**B) via a discharge passage **52** which is provided in the cover plate **12**. The oil is discharged from the discharge area in which the pump chamber **40** is compressed in conjunction with the rotation of the rotor **22**.

In this case, when the vane **24** rotating together with the rotor **22** is at a rotating angle position heading for the suction area from the discharge area mentioned above (which is also called as a maximum pressing rotational position of the vane **24**), during one rotation of the rotor **22**, the vane **24** is pressed into the vane groove **23** most deeply by the cam surface **30**A of the cam ring **30**. Further, when the vane **24** is at a rotating angle position heading for the discharge area from the suction area mentioned above (which is also called as a maximum pushing out rotational position of the vane **24**), the vane **24** is pushed out most significantly to an outer side of the vane groove **23** by the cam surface **30**A of the cam ring **30**.

The pump unit **20** is provided with a high pressure chamber **54** which is defined by the inner side plate **31**, in a farthest portion of the concave portion **11**A of the housing **11**. The inner side plate **31** has a high pressure oil supply port **55** which communicates the discharge port **51** provided in the cam ring **30** with the high pressure chamber **54**, and the oil discharged from the discharge port **51** on the basis of the rotation of the rotor **22** is supplied to the high pressure chamber **54**.

The inner side plate **31** is structured, as shown in FIG. **4** and FIG. **5**, such that a circular arc shaped high pressure oil introduction port **56**A conducting the high pressure discharge oil in the high pressure chamber **54** to a space **23**A close to a bottom portion of the vane groove **23** in a part of the peripheral direction of the rotor **22** is provided at two positions which are opposed to each other around the center hole **31**A on the same diameter of the inner side plate **31**. Further, the outer side plate **32** is provided in a surface which comes into contact with another side surface of the rotor **22**, with an annular back pressure groove **57** which is communicated with the space **23**A close to the bottom portion of the vane groove **23** in a whole portion of the rotor **22**, and is communicated with the high pressure chamber **54** via the high pressure oil introduction port **56**A mentioned above of the inner side plate **31**. In this case, the inner side plate **31** is provided with a circular arc shaped communication groove **56**B which is communicated with the space **23**A close to the bottom portion of the vane groove **23** in a part of the peripheral direction of the rotor **22**, at two positions which are pinched by the adjacent two high pressure oil introduction ports **56**A and **56**A on the surface coming into contact with the one side surface of the rotor **22**.

In this case, the high pressure oil introduction port **56**A of the inner side plate **31**, the communication groove **56**B and the back pressure groove **57** of the outer side plate **32** are set in such a manner as to be communicated with the space **23**A close to the bottom portion of the vane groove **23** which is defined by base ends Ei (i=1, 2, 3, . . .) of the vane **24** within the vane groove **23**, whatever rotational position Ni (i=1, 2, 3, . . .) the rotor **22** is provided at in a rotating forward direction N. In this case, in FIG. **5**, reference symbol N**1** corresponds to a maximum pressing rotational position of the vane **24**, and reference symbol N**3** corresponds to a maximum pushing out rotational position of the vane **24**.

In accordance with this, the high pressure discharge oil which is discharged from the discharge port **51** so as to be supplied to the high pressure chamber **54** on the basis of the rotation of the rotor **22** is supplied to the annular back pressure groove **57** of the outer side plate **32** via the high pressure oil introduction port **56**A of the inner side plate **31**, and further via the space **23**A close to the bottom portion of the vane groove **23** in a part of the rotor **22** with which the high pressure oil introduction port **56**A is communicated. The high pressure discharge oil supplied to the annular back pressure groove **57** of the outer side plate **32** is simultaneously introduced to the space **23**A close to the bottom portion of the vane groove **23** in a whole portion of the rotor **22** with which the back pressure groove **57** is communicated, and presses the leading end of the vane **24** against the cam surface **30**A in the inner periphery of the cam ring **30** on the basis of the pressure of the high pressure discharge oil which is introduced to the space **23**A close to the bottom portion of the vane groove **23** so as to bring it into contact. In this case, the high pressure discharge oil which is introduced to the space **23**A close to the bottom portion of the vane groove **23** of the rotor **22** which is not communicated with the high pressure oil introduction port **56**A of the inner side plate **31** is pressed into the communication groove **56**B of the inner side plate **31** so as to be filled.

Accordingly, in the vane pump **10**, if the rotating shaft **21** is rotated by the internal combustion engine, and the leading end of the vane **24** of the rotor **22** is rotated while being pressed against the cam surface **30**A in the inner periphery of the cam ring **30**, the oil from the suction port **41** is sucked into the pump chamber **40** which is expanded in conjunction with the rotation of the rotor **22**, in the suction area in the upstream side of the rotation forward direction of the rotor **22**. At the same time, in the discharge area in the downstream side of the rotation forward direction of the rotor **22**, the oil from the pump chamber **40** which is compressed in conjunction with the rotation of the rotor **22** is discharged to the discharge port **51**.

In the present embodiment, the discharge port **51** is provided in each of two positions which are opposed in the diametrical direction passing through the center C of the rotor **22** (the center J of the cam ring **30** and the outer side plate **32**). One of these two discharge ports **51** is set to a main discharge port **51**M, and another is set to a sub discharge port **51**S. These two discharge ports **51**M and **51**S are arranged so as to be point symmetrical with respect to the centers K and L mentioned above.

The main discharge port **51**M is connected to the discharge passage **52** and the discharge port **53** so as to always supply the discharge oil to the fluid equipment. The sub discharge port **51**S is communicated with the discharge passage **52** and the discharge port **53** by a communication passage which is not illustrated, however, a flow path switch valve is provided in the communication passage, thereby switch communicating with a tank side passage which is branched from the flow path switch valve (or the suction port **41**S corresponding to the sub discharge port **51**S).

In the low rotation area of the internal combustion engine and the rotor **22**, a sufficient flow rate of pressure oil is supplied to the fluid equipment from both of the main discharge port **51**M and the sub discharge port **51**S. Further, in the high rotation area, only the main discharge port **51**M supplies the pressure oil to the fluid equipment, and the discharge oil of the sub discharge port **51**S is flowed back as a surplus oil to the tank side (or the suction port **41**S), thereby achieving a reduction of a consumed horse power.

Further, in the vane pump **10**, there are provided V-shaped notch grooves V**1** and V**2** which are extended from a hole edge in an inverse direction to the rotation forward direction of the rotor **22** so as to be narrower little by little in the inverse direction, in the main discharge port **51**M and the sub discharge port **51**S. In accordance with this, in the pump unit **20**, a communication start point between each of the pump chambers **40** and each of the discharge ports **51**M and **51**S is quickened on the basis of an existence of the notch grooves V**1** and V**2**, and a communication time between the pump chamber **40** and the discharge ports **51**M and **51**S becomes longer with respect to the rotating speed of the vane **24**. Therefore, as a moving time of the working fluid pressure within the discharge ports **51**M and **51**S to the pump chamber **40** becomes longer, a hydraulic pressure change of the working fluid within the pump chamber **40** becomes smaller. As a result, it is possible to reduce a surge pressure within the pump chamber **40** and it is possible to reduce abnormal noise generation.

Further, in the vane pump **10**, the main discharge port **51**M is connected to the discharge passage **52** and the discharge port **53** so as to always supply the discharge oil to the fluid equipment, and the main discharge port **51**M is set to the discharge port **51** in a high discharge pressure side in which the discharge pressure is higher. On the other hand, the sub discharge port **51**S comes to the discharge port **51** in a low discharge pressure side in which the discharge pressure is low, at a time of being connected to the tank side (or the suction port **41**S) by the flow path switch valve. In the vane pump **10**, taking into consideration a matter that the discharge pressures of the respective discharge ports **51**M and **51**S are different from each other, an extension length L1 of the notch groove V**1** which is provided in the main discharge port **51**M in the high discharge pressure side is set longer than an extension length L2 of the notch groove V**2** which is provided in the sub discharge port **51**S in the low discharge pressure side.

Further, in the vane pump **10**, two vanes **24** and **24** which are positioned in both sides while holding the center C of the rotor **22** therebetween so as to be opposed are provided on the diameter of the rotor **22**. When the center C of the rotor **22** displaces close to the sub discharge port **51**S in a side of the low discharge pressure at a degree of a play of a serration connection with the rotating shaft **21** as shown in FIG. **6**A to FIG. **6**B, a timing at which the one vane **24** runs into the leading end of the notch groove V**1** of the main discharge port **51**M in the side of the high discharge pressure is set at same time as a timing at which the another vane **24** runs into the leading end of the notch groove V**2** of the sub discharge port **51**S in the side of the low discharge pressure.

The extension length L1 of the notch groove V**1** of the main discharge port **51**M and the extension length L2 of the notch groove V**2** of the sub discharge port **51**S are set according to an amount of the play of the serration connection between the rotating shaft **21** and the rotor **22**, and a pressure difference of the discharge pressure between the main discharge port **51**M and the sub discharge port **51**S.

Accordingly, when the vane pump **10** discharges the pressure fluid to the fluid equipment only from the main discharge port **51**M, the main discharge port **51**M is set to the discharge port **51** in the side of the high discharge pressure, and the sub discharge port **51**S is set to the discharge port **51** in the side of the low discharge pressure, the vane pump **10** is actuated as follows.

When the discharge pressures of the respective discharge ports **51**M and **51**S of the vane pump **10** are different from each other, the extension length L1 the notch groove V**1** which is provided in the main discharge port **51**M in the side of the high discharge pressure is set longer than the extension length L2 of the notch groove V**2** which is provided in the sub discharge port **51**S in the side of the low discharge pressure. As a result, a relationship Fa>Fb is established between a pressure Fa which the working fluid pressure within the main discharge port **51**M in the side of the high discharge pressure applies to the rotor **22** via the pump chamber **40**, and a pressure Fb which the working fluid pressure within the sub discharge port **51**S in the side of the low discharge pressure applies to the rotor **22** via the pump chamber **40**, on the diameter of the rotor **22** which connects the main discharge port **51**M in the side of the high discharge pressure and the sub discharge port **51**S in the side of the low discharge pressure through the center C of the rotor **22**. The pressure difference Fa/Fb makes the center C of the rotor **22** displace from the center J of the cam ring **30** at a degree of the play of the serration by which the rotor **22** is connected to the rotating shaft **21**, as shown in FIG. **6**A to FIG. **6**B, and goes on maintaining the rotor **22** at the offset position in FIG. **6**B. Further, since the extension length L1 of the notch groove V**1** of the main discharge port **51**M in the side of the high discharge pressure is longer than the extension length L2 of the notch groove V**2** of the sub discharge port **51**S in the side of the low discharge pressure (A>B), even if the center C of the rotor **22** is offset from the center J of the cam ring **30** as mentioned above, the timing at which the one vane **24** runs into the leading end of the notch groove V**1** of the main discharge port **51**M in the side of the high discharge pressure comes to the same as the timing at which the another vane **24** runs into the leading end of the notch groove V**2** of the sub discharge port **51**S in the side of the low discharge pressure, in these two vanes **24** and **24** which are opposed to each other while holding the center C of the rotor **22** therebetween. Therefore, the timings at which the respective pump chambers **40** zoned by the vanes **24** and **24** are communicated respectively with the main discharge port **51**M in the side of the high discharge pressure and the sub discharge port **51**S in the side of the low discharge pressure are the same, phases of the pulsations of the hydraulic pressure within the respective discharge ports **51**M and **51**S are synchronized with each other, and it is possible to hold down an abnormal noise generation.

In this case, when the vane pump **10** discharges the pressure fluid to the fluid equipment from both of the main discharge port **51**M and the sub discharge port **51**S, both of the main discharge port **51**M and the sub discharge port **51**S come to the discharge port **51** in the side of the high discharge pressure having the same pressure, and the vane pump **10** is actuated as follows.

When the one vane **24** runs into the leading end of the longer notch groove V**1** of the main discharge port **51**M, and the another vane **24** does not run into the leading end of the shorter notch groove V**2** of the sub discharge port **51**S yet in these two vanes **24** and **24** which are positioned in both sides while holding the center C of the rotor **22** therebetween so as to be opposed to each other, the working fluid pressure within the main discharge port **51**M is added to the rotor **22** via a whole area of the pump chamber **40** which is zoned by the one vane **24**. On the basis of the pressure of the working fluid pressure within the main discharge port **51**M, the center C of the rotor **22** displaces from the center J of the cam ring **30** as shown in FIG. **6**A to FIG. **6**B at the degree of the play of the serration by which the rotor **22** is connected to the rotating shaft **21**, and positions the rotor **22** at an offset position in FIG. **6**B. The another vane **24** immediately runs into the leading end of the shorter notch groove V**2** of the sub discharge port **51**S on the basis of the offset of the center C of the rotor **22**, and the working fluid pressure within the sub discharge port **51**S is added to the rotor **22** via a whole area of the pump chamber **40** which is defined by the another vane **24**. Accordingly, the timings at which the respective pump chambers **40** zoned by the vanes **24** and **24** are communicated respectively with the main discharge port **51**M and the sub discharge port **51**S are the same as each other, the phases of the pulsation of the hydraulic pressure within the respective discharge ports **51**M and **51**S are synchronized with each other, and it is possible to hold down abnormal noise generation.

Even if each of the respective vanes **24** and **24** rotate within each of the discharge ports **51**M and **51**S after passing through the leading ends of the notch grooves V**1** and V**2** of each of the discharge ports **51**M and **51**S, the discharge pressures of both the discharge ports **51**M and **51**S which act on the rotor **22** via the pump chambers **40** zoned by the vanes **24** are the same pressure, and goes on maintaining the rotor **22** at the offset position in FIG. **6**B, without pushing back the center C of the rotor **22** close to the center J of the cam ring **30** from the offset position in FIG. **6**B.

In this case, the present invention is not limited to the vane pump in which a plurality of discharge ports consist of the main discharge port **51**M in the side of the high discharge pressure and the sub discharge port **51**S in the side of the low discharge pressure such as the embodiment mentioned above, but can be applied to a vane pump in which one comes to the discharge port in the side of the high discharge pressure and another comes to the discharge port in the side of the low discharge pressure on the basis of a difference of a flow path resistance of discharge paths of respective discharge ports.

As heretofore explained, embodiments of the present invention have been described in detail with reference to the drawings. However, the specific configurations of the present invention are not limited to the illustrated embodiments but those having a modification of the design within the range of the presently claimed invention are also included in the present invention.

In accordance with the present invention, there is provided a vane pump comprising: a rotor which is connected to a rotating shaft pivoted to an inner portion of a housing so as to rotate. A cam ring is arranged in such a manner as to surround the rotor in the inner portion of the housing. A plurality of vanes are slidably arranged in a plurality of vane grooves provided in a radial direction of the rotor. A plurality of pump chambers are defined by the adjacent vanes around the rotor. A plurality of discharge ports corresponding to the pump chambers carrying out a compression stroke, which are provided to be opposed in a diametrical direction of the rotor. Notch grooves are provided each of which is extended from a hole edge in an inverse direction to a rotor rotating forward direction of each of the discharge ports to the inverse direction. When discharge pressure of the discharge ports are different from each other, an extension length of the notch groove which is provided in the discharge port in a side of a high discharge pressure is set longer than an extension length of the notch groove which is provided in the discharge port in a side of a low discharge pressure. Accordingly, it is possible to synchronize phases of pulsations of a hydraulic pressure within respective discharge ports with each other so as to hold down an abnormal noise generation, at a time when discharge pressures of the respective discharge ports are different from each other, in a vane pump having a plurality of discharge ports which are provided with notch grooves for reducing a serge pressure within a pump chamber defined by adjacent vanes.

Although the invention has been illustrated and described with respect to several exemplary embodiments thereof, it should be understood by those skilled in the art that the foregoing and various other changes, omissions and additions may be made to the present invention without departing from the spirit and scope thereof. Therefore, the present invention should not be understood as limited to the specific embodiment set out above, but should be understood to include all possible embodiments which can be encompassed within a scope of equivalents thereof with respect to the features set out in the appended claims.

What is claimed is:

1. A vane pump comprising:

a rotor which is connected to a rotating shaft pivoted to an inner portion of a housing so as to rotate;

a cam ring which is arranged in such a manner as to surround the rotor in the inner portion of the housing, said cam ring being fixed with respect to the housing;

a plurality of movingly rotatable vanes which are slidably arranged in a plurality of vane grooves provided in a radial direction of the rotor;

a plurality of pump chambers which are defined by the adjacent vanes around the rotor;

a high pressure discharge port and a low pressure discharge port defined in said cam ring corresponding to the pump chambers carrying out a compression stroke, the high pressure discharge port being opposingly disposed from the low pressure discharge port along a diameter direction of the rotor; and

a high pressure notch groove and a low pressure notch groove defined in an outer side plate of the vane pump, the high pressure notch groove extending in a direction away from an edge of the high pressure discharge port and the low pressure notch groove extending in a direction away from an edge of the low pressure discharge port,

a length of the high pressure notch groove is greater than a length of the low pressure notch groove, and a first vane and a second vane of the plurality of movingly rotatable vanes are respectively positioned on opposite portions of the rotor so as to be opposed one-to-another along the diameter direction of the rotor, the rotor having two positions during operation of the vane pump, a first unshifted position and a second shifted position, the shifting occurring due to a force applied to the rotor resulting from differing pressures occurring respectively at the high pressure discharge port and the low pressure discharge port as the vane pump transitions from a static state to an operating state, and when the rotor is disposed in the second shifted position the center of the rotor is disposed closer to the low pressure discharge port on the side of the vane pump having the low discharge pressure, wherein when the rotor is disposed in said second shifted position said first vane of the plurality of movingly rotatable vanes encounters a leading end of the high pressure notch groove at the high pressure discharge port in a side of the vane pump having the high discharge pressure in a rotation direction of the rotor at the same moment at which said second vane of the plurality of movingly rotatable vanes encounters a leading end of the low pressure notch groove at the low pressure discharge port in a side of the vane pump having the low discharge pressure in the rotation direction of the rotor.

2. The vane pump according to claim **1**, wherein the high pressure notch groove and the low pressure notch groove are V-shaped, respectively, and the open end of the V-shape of the high pressure notch groove is disposed adjacent the edge of the high pressure discharge port and the open end of the V-shape of the low pressure notch groove is disposed adjacent the edge of the low pressure discharge port.

3. The vane pump according to claim **2**, wherein the different respective lengths of said V-shaped high pressure notch groove and said V-shaped low pressure notch groove correspond to an amount of a play between the rotating shaft and the rotor manifested from a pressure difference of a discharge pressure between the high pressure discharge port and the low pressure discharge port.

4. The vane pump according to claim **3**, wherein the vane pump is a fixed displacement vane pump.

5. The vane pump according to claim **2**, wherein the vane pump is a fixed displacement vane pump.

6. The vane pump according to claim **1**, wherein the vane pump is a fixed displacement vane pump.

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